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Mr. Tim LeBaron
Hearing Officer
National Transportation Safety Board
Via e-mail: timothy.lebaron@ntsb.gov

Subject: Information Requested during the NTSB Investigative Hearing, held 11 December 2013 on the Asiana 777 Landing Accident at San Francisco

Reference: Transcript from the subject NTSB Investigative Hearing

Dear Mr. LeBaron:

During the recent investigative hearing concerning the Asiana 777 Landing Accident at San Francisco, two follow-up requests were made to Boeing witnesses. The requests are repeated below followed by our response:

1. (Weener request) Provide documentation that describes the process by which Boeing determines the alert level (warning, caution or advisory) for an alert and the modes of annunciation (aural, visual, tactile).

2. (Sumwalt request) Submit for the record, any data that Boeing may have used in the assumption that pilots are very good at monitoring.

The specific requests and our response are included as an enclosure to this letter.

If you have any questions, please contact Mr. Mark H. Smith at 425-237-2967, or via e-mail at mark.h.smith2@boeing.com.

Best regards,

[redacted]

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Enclosure: Information Requested during the NTSB Investigative Hearing

Information Requested during NTSB Investigative Hearing held 11 December 2013, on Asiana 777 Landing Accident at San Francisco

Request 1 (Hearing Transcript Page 78, Line 11)
MEMBER WEENER: So given the time, can I ask that we get some of that information submitted for the record? So if you have a formal process with established criteria, if you could provide that for us, to decide the level of warning, what the information channel is, whether that's audible, visual, tactile, et cetera, and how it's targeted for either the pilot flying, pilot monitoring or both. So rather than take the time now, if you have that process, could you just submit that for the record?

Response: Boeing defines flight crew alerts on the 777 to be one of four levels; Time Critical, Warning, Caution or Advisory. These alert levels are defined in the 777 Design Requirements and Objectives document (DR&O) as follows:

- Time Critical: An operational condition which requires immediate pilot awareness and immediate corrective or compensatory action to maintain safe flight.
  (e.g. WINDSHEAR and PULL UP)
- Warning: An operational or aircraft system condition which requires immediate crew awareness and immediate pilot corrective or compensatory action.
  (e.g. Autopilot Disconnect and Engine Fire)
- Caution: An operational or aircraft system condition which requires immediate crew awareness. Compensatory or corrective action may be required.
  (e.g. Autothrottle Disconnect and Speedbrakes Extended)
- Advisory: An operational or aircraft system condition which requires crew awareness. Compensatory or corrective action may be required.
  (e.g. Fuel Pump or Air Data Probe Heat)

Boeing's design process involves an interdisciplinary team of Test Pilots, Training Pilots, Engineers of various disciplines and Human Factors Experts to review individual crew alert implementations to assure each is presented at the correct alert level, that it is salient and that it is set for the correct conditions. Every EICAS airplane alert is subjected to this review. At the same time the crew alerts are defined, the flight crew procedures (corrective or compensatory actions) are developed. This makes sure the presentation of the crew alert, the conditions that set the alert, and the crew procedure or actions in response to the alert are all mutually supported and coordinated.

The general methods of annunciation for each alert level vary to support the level of criticality.

- Time Critical alerts are indicated with master warning lights, unique visual text messages in the flight crew's primary field of view, and unique voice aural alerts specific to the alert condition.
- Warning alerts are indicated with master warning lights, unique visual text messages on the EICAS display, and with either a unique non-voice aural (e.g. wailer for autopilot disconnect) or a shared master warning siren used for most warning alerts.
- Caution alerts are indicated with master caution lights, unique visual text messages on the EICAS display and a shared master caution non-voice aural beeper.
- Advisory alerts are indicated with unique visual text messages on the EICAS display.

Some alerts do not precisely follow these conventions due to regulatory requirements, retrofit considerations, or for the purpose of industry standardization. These include some of the Enhanced Ground Proximity System caution alerts and TCAS Resolution Advisories.

Request 2 (Hearing Transcript Page 185, Line 12)
MEMBER SUMWALT: Thank you. I'd like to ask that for the record you submit any data that Boeing may have used in the assumption, like you said this morning, that we assume that pilots are very good at monitoring. Any data that you may have to support that, we'd like to have please. Thank you.

Response: Boeing flight deck designers believe: (1) pilot monitoring skills vary with phase of flight, duration of the monitoring task, and most importantly, the criticality of the information being monitored; (2) pilots are most proficient at monitoring those parameters needed to accomplish the current task, such as flight parameters during manual flight, or the selected VHF radio frequency when transitioning sectors; and (3) pilots are less vigilant in monitoring flight parameters over extended periods such as oceanic cruise.

With this in mind, Boeing flight deck designers assume human errors or failures in vigilance are inevitable and will occur. Boeing flight decks have features built in to support effective pilot monitoring and to mitigate possible lapses in monitoring. These include formatting techniques such as the use of color and highlighting cues, performance data, limit markings, reminders, aurals, and tactile cues such as stick shaker. The amount of mitigation provided through these features is proportional to the severity of the potential error. For example, the hierarchy of mitigations for low airspeed is much more robust than the mitigations for an improperly set radio frequency, because the consequence of a stall is more hazardous than the consequence of a frequency mis-set.

The academic literature on this subject supports many of the beliefs underlying Boeing's design philosophy. For example, a study documented by Sarter, Mumaw and Wickens in 2001 and 2007, found that pilots monitored the primary flight display almost twice as often during descent and landing than they did while at cruise. This study also found that pilots more closely monitor critical information, such as primary flight parameters.

Boeing flight deck designers further assume that when pilots become task saturated or confused about the state of the airplane, whether due to the operational situation, airplane failures, or crew errors, the crew will work together to fly the airplane and reduce the level of automation to a level appropriate for the situation. Flying the airplane manually is the ultimate mitigation step for the aircrew. The flight deck design supports this philosophy. Both crew members are kept aware of control inputs with backdriven, large displacement controls. Critical flight parameters like airspeed, altitude, attitude, thrust, and heading are located directly in front of the pilots in their primary field of view, include large fonts and graphics, and are displayed at all times. Performance information is synthesized and presented as simply as practical. Other important information, such as system status and flight mode annunciations, is prioritized to increase the likelihood that the pilots will see it in a timely manner. Less important information is available for selection by the crew, but is not displayed full time so the displays will not become cluttered and potentially distract the crew from the more important information.

Boeing has validated this design philosophy through decades of analysis, testing, certification, and in-service experience. This validation has included audit teams and design commissions populated by pilots and human factors specialists from industry, academia and government regulators; reviews and flight tests by industry and customer pilots; simulator studies and lengthy flight test programs. Data that specifically validates the design assumptions around pilot monitoring capabilities has not been collected, but in

the course of monitoring the in-service performance of our airplanes, we continue to believe that our flight deck designs are appropriate for pilot monitoring of parameters critical to successfully and safely flying our airplanes.

In summary, Boeing flight decks are designed to support flying the airplane safely as the top priority for the crew. The designers assume pilots have the knowledge, skills and training to reduce automation and operational complexity as needed to ensure the safe operation of the plane. The flight deck makes available a wealth of information and assumes that, despite a strict and robust information management scheme, pilot errors including monitoring lapses will occur. A hierarchy of mitigations is provided to assist the pilots in maintaining safe operation of the airplane. This design concept has been proven effective over decades of in-service experience and declining accident/incident rates. As the complexity of the global aviation infrastructure increases, Boeing will continue to evaluate our flight deck designs and potential enhancements.